High quality treatment planning with proton transmission Flash

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INTRODUCTION

An investigation into the dosimetric performance of ultra-high dose rate (Flash) Radiotherapy with single energy (250MeV) protons where the goal is for dose to be deposited into the patient in the plateau region (prior to the Bragg Peak used in traditional IMPT proton plans).

AIM

By investigating different treatment sites and fraction sizes (34Gy – 10Gy), we am to understand which anatomical treatment sites and prescriptions may be reasonable candidates for a future clinical study from the perspective of the achievable dose distributions (ignoring any potential sparing benefit of the Flash effect).

METHOD

Dosimetric scorecard evaluation was utilized on a pre-release version of the Varian FLEX Planning System 2.0. Two novel features in this software allow the user to create ultra-high dose rate treatment plans (greater than 40Gy/s): the minimum MU objective applied during optimization and the target specific "optimized" beamline/spot list. The optimization objective penalizes spots with MU lower than specified which keeps the beam current high and, in turn, increases the dose rate. The optimized beamline places spots not on a rectangular or hexagonal grid, but instead traces the target outline (plus any specified margin) and evenly distributes remaining spots inside (all relative to specified spot distance) to achieve dose conformity and homogeneity.

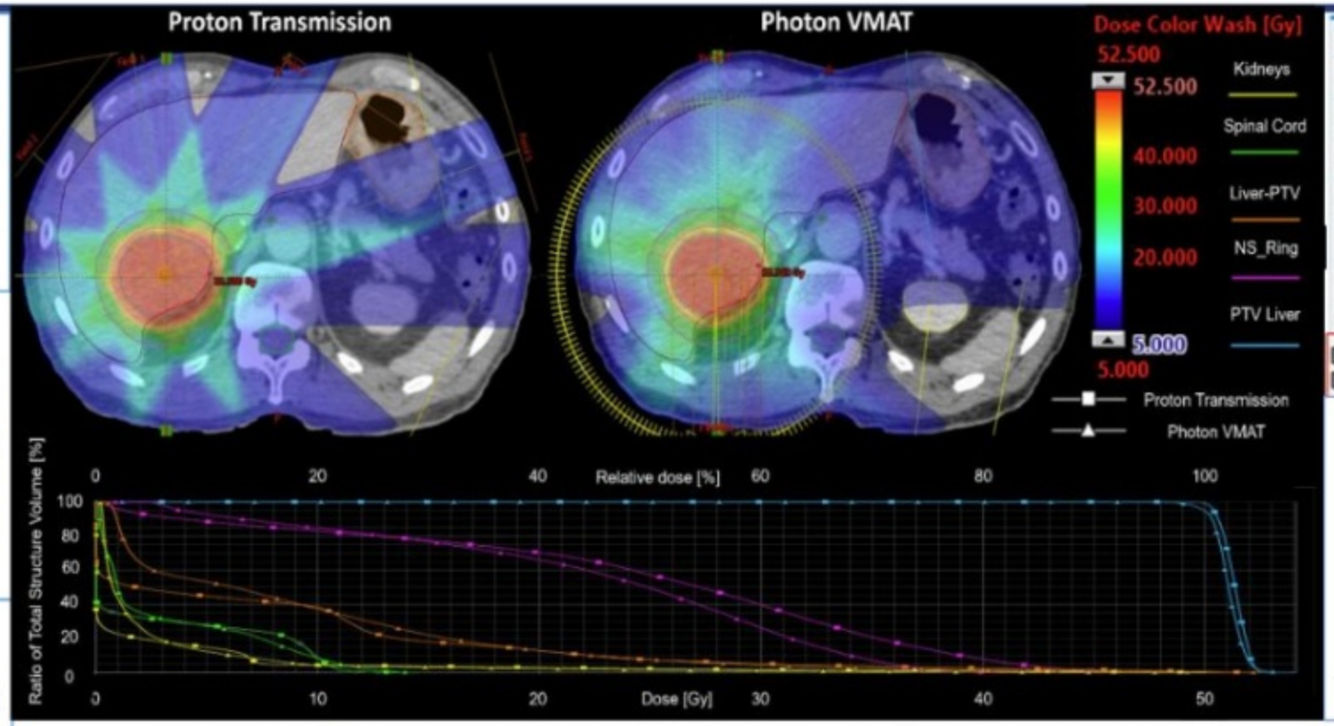

Figure 1: Isodose and DVH comparison of 5 field 250MeV proton transmission vs photon VMAT (single representative case)

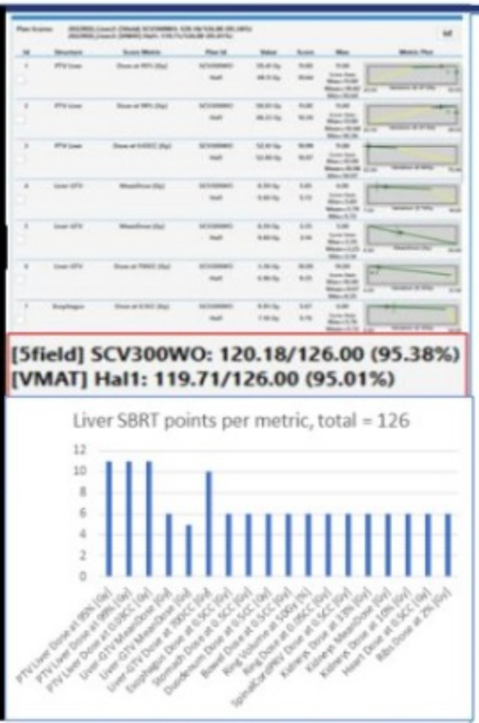

Figure 2: Liver SBRT scorecard results (top) scoring points summary (bottom)

RESULTS / SCORES

Peripheral lung case: 24.7cc PTV (34Gy, 1 fraction scorecard out of 143.5 total points)

5 field 250MeV	136.46 (CI:1.33)
IMPT 2 field	136.03 (CI:1.39)
IMPT 3 field	138.42 (CI:1.36)
IMRT 12 field	136.56 (CI:1.08)
VMAT 4 arcs	139.49(CI:1.05)

Liver SBRT case: 65.1cc PTV (50Gy, 10Gy/fraction scorecard out of 126 total points)

5 field 250MeV plan	120.18
4 arc VMAT	119.71

Spine SBRT case: 55.4cc T10_PTV (24Gy single fraction scorecard out of 310 points)

10 field 250MeV plan	277.31
IMPT 3 field	257.38
2 partial arc VMAT	272.67

Brain mets SRS case: 2.3cc, total 3 PTVs (24Gy single fraction scorecard out of 427points)

6 field 250MeV plan	311.86
6 arc VMAT	362.36

CONCLUSIONS

These dosimetric results provide evidence of comparable levels of plan quality for those who might be skeptical of using the plateau region of the proton beam when they are accustomed to the Bragg Peak and help promote further research with the available delivery technology that can achieve such high dose rates at clinically useful depths today.

Flash radiotherapy research is ongoing with several important questions left unanswered regarding beam overlaps, fractionation, the Flash sparing effect potential, and how these dose delivery variables could impact it. This study simply investigates if proton beams at 250MeV constrained into ultra-high dose rates via enforced high MU (nozzle current) have the potential to create treatment plans with high dosimetric quality compared to standard of care. The "optimized" beamline is implemented as described by Rehman et al [1].

In the four treatment site case examples provided these 250MeV examples are slightly inferior, almost equivalent or slightly superior, compared to standard of care, as quantified by their associated dosimetric scorecard. Additional cases are needed to also demonstrate where the fraction dose is too low or target size too large to utilize this 250MeV proton delivery technique while still achieving ultra-high dose rates.

Flash therapy is under development and not available for commercial sale.

REFERENCES

[1] Ur Rehman M et al. 2019 An optimized approach for robust spot placement in proton pencil beam scanning. Physics in Medicine & Biology 64.23: 235016.

CONTACT INFORMATION

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